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ORIGINAL CONTRIBUTION

A review of TRIZ and its benefits & challenges in stimulating creativity in problem solving of pre-university students: A TARUC case study

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Abstract. Theory of Inventive Problem Solving (TRIZ), which emerged from Russia in the 1960s, has been introduced to Tunku Abdul Rahman University College (TARUC) since 2011 to train undergraduate and pre-university students in problem solving. This paper takes a step away from conventional TRIZ literature by exploring the benefits and challenges of teaching TRIZ to pre-university students. The study serves as a preliminary study of the TRIZ program and uses quantitative and qualitative methods on 28 students to gauge the effectiveness of TRIZ tools in supporting problem finding and idea finding in solving complex ill-structured problems. Descriptive analysis shows the improvement in problem finding, idea finding, and overall problem solving after the TRIZ program. The benefits of each TRIZ tool in problem finding and idea finding were uncovered through the open-ended survey. Students also reported the benefits and challenges of learning TRIZ. This paper is potentially useful for TRIZ instructors on how to effectively teach TRIZ to pre-university students.

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INTRODUCTION

Creativity is problem solving (Guilford, 1959). Problem is a situation where someone needs to go through a process of finding the solution (Krulik and Jesse, 1987; Lewis, 2009). Over the years, many scholars and educational bodies have stressed the important of problem solving skills in students (Hafizah *et al*., 2012; Lee, 2014; National Academy of Engineering, 2005; Sabato, 2011). Problem solving is an important skill that students must have in order to cope with the demand of the 21st century whereby there is an unprecedented growth in technology where new technologies and tools are discovered dailies and are outdated at a very fast pace (Beers, 2012; Fong *et al*., 2014; Larson and Teresa, 2011; Ministry of Education, 2013). Furthermore, creativity is the back bone of Malaysia's economy (World Report, 2010).

Individuals that engaged in creative activities often have to deal with solving complex ill-structured problems that requires problem finding before generating idea in the idea finding stage because ill-structured problems seldom have clear problem statements (Reiter-Palmon *et al*., 1997; Simon, 1996; Zeng *et al*., 2011). As a result, students should be taught explicitly how to solve complex ill-structured problems.

Decades of researches have shown that creativity is a skill that can be learned (Iryani and Murtiwidayanti, 2017; Ma, 2009; Scott *et al*., 2004; Yasin and Nor Shairah, 2014).

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Scott *et al*. (2004) conducted meta-analysis on 70 studies of creativity training program. They found that a well-designed creativity training programs is effective for people of all ages in both academic and organizational setting. Training programs using Theory of TRIZ has been found to be effective on creativity (Yasin and Nor Shairah, 2014). TRIZ has been introduced to (TARUC) since 2011 to train undergraduate and pre-university students in problem solving.

There are many TRIZ literatures on how TRIZ provides support to undergraduate students especially in the area of Mechanical Engineering. However, this paper takes a step away from conventional TRIZ literature, by exploring the benefits and challenges of pre-university students in TRIZ program and their efficacy in problem solving, problem finding and idea finding after learning TRIZ. Furthermore, this paper attempts to uncover the methodologies and tools that support problem finding and idea finding. The result of this study will enhance the teaching and training of problem solving among pre-university students.

LITERATURE REVIEW

Problem Solving

Malaysia fresh graduates are lacking in problem solving skills. The National Graduate Employability Blueprint 2012-2017 reports that employers were complaining that the fresh graduate were unable to solve problem. This is one of the reasons that hindered their employment (Ministry of Higher Education, 2012). The Malaysia education blueprint 2013-2025 mentions that the science education such as Science, Technology, Engineering and Mathematics (STEM) is tasked with instilling higher order thinking skills such as problem solving. However, the teaching and learning approaches for STEM is too teacher-centered and exam oriented (Ministry of Education, 2013). As a result, Malaysian students often resort to memorizing and rote learning to 'digest' the information than understanding (Hafizah *et al*., 2012).

Students are often taught to solve well-structured problems and seldom taught to solve complex problems which are ill-structured. Well-structured problems have a clear condition, approved method of solving and a correct answer (Guin and Andrzheyuskaya, 2012; Jonassen, 2010; Sternberg, 2012). Well-structured problems demand right answers and do not encourage the development of the use of creativity (Snyder and Mark, 2008; Sternberg, 1990; Vance *et al*., 2012).

Complex problems are ill-structured. Solving complex problems requires creativity because they that have many answers, ill-defined, and many ways of solving (Alhusaini and June, 2011; Jonassen, 2010; Suharti and Pramono, 2016). Jonassen (2000, 2010) mention that the transition from solving well-structured problem into solving ill-structured problems is not easy because it requires creativity. Woods *et al*. (1997) argue that students have difficulty transferring the process of solving well-structured problem to the more complex ill-structured problems. As a result students should be taught explicitly how to solve complex ill-structured problems.Creativity enhances learning by making it more meaningful than simple rote learning (Palaniappan, 2008; Schacter *et al*., 2006). Furthermore, (Leahy and John, 2008) discovered that students who imagine carrying out a task's instructions outperformed those who simply studied and/or memorized the instructions.

History of TRIZ

TRIZ is an acronym for the Russian phrase "Teoriya Resheniya Izobretatelskikh Zadatch" or "The Theory of Inventive Problem Solving". TRIZ can be defined as the science of innovation that consists of methodology for finding creative solutions using a collection of tools

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to direct creative thinking through accessing the past engineering and scientific knowledge (Bowyer, 2008; Cameron, 2010; Gadd, 2011; San *et al*., 2009).

TRIZ was discovered by a Russian engineer, scholar, and inventor, Altshuller, in 1999. He reviewed patents looking for clues about how people solve inventive problems which possess a major challenge for inventors and problem solvers (Guin and Guin, 2009). Inventive problems are problems that require solving contradictory feature in a system where the improvement of one feature leads to the worsening of another feature. Inventive problem is a complex problem because it has many ways of solving.

TRIZ Concept

There are five important TRIZ concepts:
(a) Systemic approaches to problem solving
(b) Solving contradiction
(c) Ideality
(d) Trend of evolution (Bowyer, 2008; Ilevbare *et al*., 2013)

A. Systemic approaches to problem solving: The systemic approaches break down the problem into components (subsystem and super system) and find their interactions (Guin and Guin, 2009). The problem solvers must first identify the technical system where problem appear. A technical system consists of group of interrelated components (e.g., things, persons and organizations) that is designed to perform a certain function to improve the efficiency of human activities (Guin and Guin, 2009; Nakagawa, 2011). The components can be classified into subsystem and super system. A subsystem is the components that combine to form a system. A Super-system consists of components that influence the system but were not designed as part of the system (San *et al*., 2009).

B. Ideality: Ideality is a concept introduced by Altshuller (1999) to evaluate the degree of appropriateness and feasibility of the solution. According to Ilevbare *et al*. (2013), an ideal system is the system that performs the functionality without generating too much harmful effects and lower cost. Ideality can be described using the following mathematical term.

$$Ideality = \frac{\sigma Functionality}{\sigma Cost + \sigma HarmfulEffects}$$

Functionality is the useful functions that a system provides (Cameron, 2010). For example, a smart phone with many applications will have more functions compare to a smart phone with lesser apps. The harmful effect is the unwanted outputs or wastes from the system. In this case, harmful effect of installing too many apps in the smart phone is the consumption of the memory space. The cost includes the monetary, resources, components and time used to provide the functionality (Cameron, 2010; Gadd, 2011; Ilevbare *et al*., 2013; Thiangthung, 2016).

C. Resource: The concept of Ideality encourages problem solvers to search for solution using resources from the environment that is easily available without any cost. If the existing resource can be used to solve problem, then they do not need to be purchased (no additional cost). Resource is defined as "the space, time, substance, energy and information, which can be employed for solving a problem" (Guin and Guin, 2009). If the solution can be found with no additional cost, then the solution is said to have moved the system closer to become ideality. The substance resources are materials that exist within a system and supersystem. Resources can also be derived from combining, transforming, concentrating, and/or intensifying the readily available resources (Pwint Oo, 2016; Terninko *et al*., 1998).

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D. Trends of evolution: Altshuller observed that the development of technical systems follow certain trends of evolution. The trends of evolution were repeated across industries and sciences (Sheu and Hei-Kuang, 2011). The trends of evolution help problem solvers to predict the future of a technical system so that better solution can be found (Gadd, 2011; Rantanen and Ellen, 2010).

E. Solving contradiction: Altshuller noticed that solving inventive problem involves solving contradiction. According to Kiatake and João (2012), solving the contradiction is the key element of innovation. There are two types of contradiction in TRIZ: Technical contradiction and physical contradiction (Ilevbare *et al*., 2013). A technical contradiction arises when the effort of improving certain feature of a system result in worsening another feature of a system. For example: making a table big to accommodate more people (improving feature) will result in the table taking up too much space (worsening feature). The physical contradiction on the other hand arises due to a system that has opposite physical requirement for different occasions such as an umbrella must have big surface to offer better protection against rain and small for convenience. The big and small are mutually opposite parameter that a system (umbrella) must have at different conditions.

TRIZ Tools

Altshuller and his colleagues had discovered and also developed many TRIZ tools since 1946 such as 40 inventive principles, 76 standard solutions, effects database, separation principles, contradiction matrix, patterns of evolution for the technical systems, idea final result, fitting, function analysis, substance field (Su-field) analysis, analysis of system resources, nine windows and etc. These tools are standalone tools. Problem solvers select the tools depending on the type of problems (Moehrle, 2005; Guin and Guin, 2009). In TARUC, the TRIZ program is based on the layout guided by Malaysia TRIZ Association (My TRIZ). So far, students are only taught TRIZ level one tools set by MyTRIZ for higher learning institution. Beginners learn TRIZ tools such as function analysis, trimming, cause and effect chain analysis, contradiction matrix and 40 inventive principles. The description of each tool is shown in Table 1.

TABLE 1 . Description of tools in TRIZ based creative problem solving module

Tools	Description
1. Functional analysis	An analysis to understand the interactions between all the components in the system and to discover the problems arising from their interactions.
2. Cause and effect chain analysis	A method to find the root cause of the problem.
3. Trimming	A method of eliminating components from a technical system so that to increase the ideality of the system.
4. 40 iventive principles	A group of 40 conceptual solutions to technical contradictions. (See appendix A for complete list).
5. Contradiction matrix	A matrix of 39 technical parameters that are arranged on the vertical and horizontal axis to interact with one another. It is used to point out the inventive principles that can be applied to solve technical contradiction.

(Ilevbare *et al*., 2013) except for cause and effect chain analysis (Nakagawa, 2011) and ideality (San *et al*., 2009)

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TRIZ Problem Solving Methodology

TRIZ provides repeatability, predictability and reliability in idea generation due to its structure and algorithmic approach (Kowaltowski *et al*., 2010). Belski *et al*. (2013) claim that TRIZ problem solving is successful due to its underlying information-processing theory. The information-processing theory of problem solving focuses on the cognitive components that involved when transforming a problem through a problem space from the initial state to the final goal state (Chi, 1985; Ohlsson, 2012). The initial state of problem can be pictured as the specific problem and the goal state is the specific solution (Figure 1). The area between the specific problem and specific solution is the problem space. A given problem can be solved in different ways using different strategies. Each strategy might produce different outcomes.

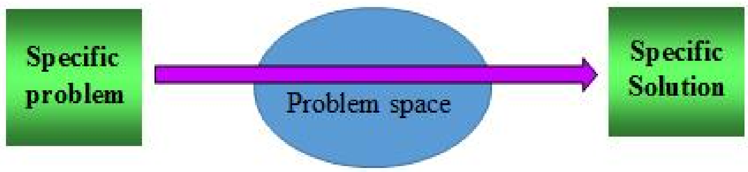

FIGURE 1 . Finding specific solution from specific problem through problem space

The 'Four-Box Scheme' problem solving method (Figure 2) has been constantly highlighted in TRIZ literatures (Cameron, 2010; Darrell, 2002; Ilevbare *et al*., 2013; San *et al*., 2009; Savransky, 2010). The typical TRIZ problem solving is to find a specific solution for a specific problem. If the breakthrough solution cannot be found through the typical problem solving method such as trial and error and brainstorming, then problems solvers can apply the TRIZ way of problem solving by generalising a specific problem into a general problem by applying TRIZ model of problem such as technical contradiction, physical contradiction, function model or substance-field model. The general problem can then be solved by using TRIZ tools such as contradiction matrix or system of standard inventive solutions. Finally, the user determines the type of specific solution based on the suggested TRIZ general solution such as 40 inventive principles or 76 standard inventive solutions. The model of solution is a specific inventive principle selected by the user to generate specific solution.

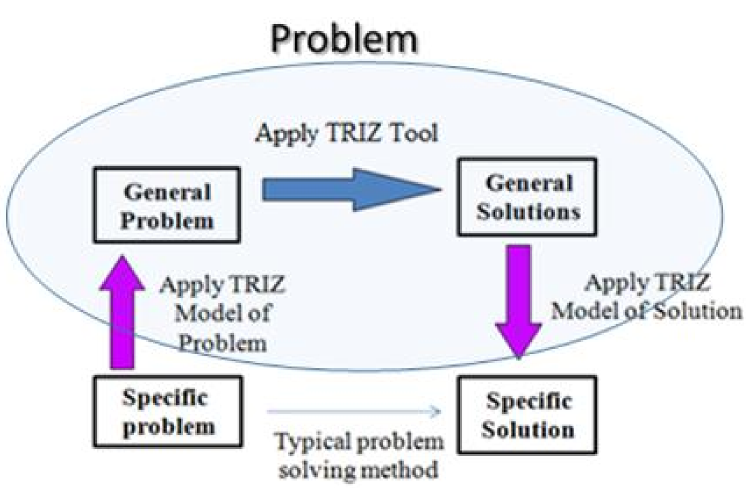

FIGURE 2 . Four box scheme. Adapted from (Cameron, 2010; Ilevbare *et al*., 2013; Darrell, 2002; Savransky, 2010; San *et al*., 2009)

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The usage of TRIZ is affected by problem solvers cognitive process. When applying TRIZ, problem solvers basically carry out the process of heuristic search to look for the best action that produces the best outcome when moving through the problem space from the specific problem in search for specific solution (Ohlsson, 2012). Heuristic is rules-of thumb for reasoning, a simplification, or an educated guess that reduces or limits the search for solutions in domains that are difficult and poorly understood (Soegaard, 2015). Furthermore, user with greater ability to reason will experienced a greater increase in idea generation when using TRIZ method (Dumas and Linda, 2015).

TRIZ in Education

Wits *et al.* (2010) suggested that TRIZ can be introduced in schools, colleges and universities by introducing modular TRIZ trainings. The teaching of TRIZ in education setting can be done through the enrichment or infusion approach (Adey and Michael, 1990; Belski *et al*., 2013; Shayer and Philip, 2002). In the enrichment, TRIZ is taught in parallel with existing domain-specific subject. As for the infusion approach, TRIZ is embedded in the syllabus of the subject (Lepeshev *et al*., 013; Pogrebnaya *et al*., 2013).

TRIZ has its root in mechanical engineering (Nakagawa, 2011). TRIZ provides support to under-graduate students and training industrial engineers on how to think creatively in problem solving (Nakagawa, 2011). TRIZ promotes innovation in education (Fan, 2010). TRIZ theory can be integrated into the innovation education syllabus for innovative creativity training in the mechanical engineering major (Fan *et al*., 2012). According to Cameron (2010), TRIZ can be learned by everyone including children. TRIZ can be taught in a matter of hours (Belski, *et al*., 2014; Filmore, 2006), days (Song *et al*., 2014), months (Belski, 2009; Han and Seung, 2014; Hernandez *et al*., 2013) or years (Barak, 2013; Belski *et al*., 2013).

Problem Solving using TRIZ

TRIZ has its root in mechanical engineering (Nakagawa, 2011). TRIZ research has resulted in the extension of TRIZ applications from the engineering domain into non-engineering areas, such as business (Domb and Darrell, 1999; Darrell, 2007), education (Chee *et al*., 2014; Mann et al., 2002; Sheng *et al*., 2012), service operations management (Zhang *et al*., 2003), quality management (Retseptor, 2003), Eco-innovative design (Chen and Wang-Chih, 2007), health service management (Lin *et al*., 2012) and Biology (Lee and Cho, 2014; Savelli, 2014).

Belski (2009) used the enrichment approach of TRIZ training. A total of 42 engineering students in their second to fourth year of study were enrolled in Royal Melbourne Institute of Technology elective course 'Systematic and Inventive Problem-solving' for 13-week semester. During the 13-week semester, the students learned four TRIZ tools: Situation Analysis, Method of the Ideal Result, Systematized Substance-Field Analysis, and the 40 Innovative Principles with the Contradiction Table. Based on pre- and post-course survey results and students reflection, students' efficacy in the abilities of problem solving have improve tremendously. Others findings were TRIZ thinking tools impacted students' problem solving abilities much more than engineering discipline-based course, improved the ability to attempt open-ended problems, improved the students' systematic thinking, improve the ability to look beyond the current knowledge.

Belski *et al.* (2013) conducted a five years longitudinal study on the training. The studies shows that TRIZ enhanced students' problem solving self-efficacy more than four years of enrolling in the engineering course. They explained that the success is due to the explicit teaching of problem representation as well as problem solving heuristic. Problem

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solving can be taught in an effective manner through the enhancement mechanism of creative thinking (Belski *et al*., 2013; Belski, 2009, 2015).

Problem finding is a process that leads to the restatement of the ill-defined problems into a set of well-defined problems. Problem finding is the integral part of creative problem solving process (Kozbelt *et al*., 2010; Runco, 1994, 2014). During the problem solving process, the ill-structured problems can be solved in a more familiar ways by redefining, reorganizing the problem space or breaking the problems into a set of well-defined problems (Gardner, 1988; Simon, 1989). When solving ill-structured problem, problem solvers have to determine whether there is a problem to solve. This is followed by constructing a model or representation that contains all the possible resources and constraints of the problem. Problem solvers also look for the possible causes of the problem before constructing a problem space (Lee and Michael, 2012; Sinnott, 1989: Voss and Post, 1988). It has been discovered that, when students pose their own problems by generation and reformulation of problems, they become more innovative and creative through the improving of problem solving skills (Franske, 2009; Shriki, 2013).

There is limited literature review on the use of TRIZ tools in problem finding. Dwyer (2005) suggested that traditional TRIZ tools are not effective in formulating a problem statement and in conducting adequate problem analysis. Harlim and Iouri (2015), suggested a few TRIZ tools suitable for problem finding include situation analysis, substance-field analysis, method of the ideal result, ARIZ, OTSM-TRIZ (General Theory of Powerful Thinking). Miller and Ellen (2002) used function analysis in generating problem statement.

Problem finding is a skill that can be trained (Fontenot, 1993). In addition, Chand and Mark (1993) discover that students can be taught problem finding through explicit instruction. However, the use of strategies and skills do not necessarily transfer from one problem type to another. This is because students' have different interpretation of the same problems, so they use different strategies to find problems.

There are two types of explicit instruction, open instruction and closed instruction (Hu *et al*., 2010). In an open instruction, the subjects generated problem statement based on a situation that did not indicate a problem. In a closed instruction, the subjects generated problem statement based on the given data of a hidden problem such as asking subjects to generate all scientific questions related to a picture of an astronaut standing on the moon. The open instruction taps into how much attention they pay to science related problems in everyday life but the closed instruction taps into the creativity of a student to use existing knowledge to find science related problems (Hu *et al*., 2010). The idea finding is the ability to generate ideas. TRIZ provides repeatability, predictability and reliability in idea finding due to its structure and algorithmic approach (Kowaltowski *et al*., 2010).

Belski *et al*. (2014) divided undergraduate students into control group and experimental group to test their idea generating to ill-defined problem. Students from a control group generated solution ideas in silence for 16 minutes. Students in an experimental group were exposed to a TRIZ tool, Subtance-Field Analysis. Students were taught eight Substance-Field Analysis Mechanical, Acoustic, Thermal, Chemical, Electrical, Magnetic, Intermolecular, Biological (MATCEMIB) for two minutes per field. Students who learned the eight fields of MATCEMIB generated 2.5 times more solution ideas compared to the students from the control group. This experiment demonstrated that simple TRIZ tools can be learnt by university students in just a few hours.

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Hernandez *et al*. (2013) studied the effectiveness of TRIZ as compared to no formal method of idea generation. The experiments were conducted simultaneously at three institutions. The participants were the graduate and the undergraduate engineering students, working a design problem. Students from each university were divided into treatment group and control group. The treatment group receives TRIZ training in the form of a power point lecture and handouts for TRIZ principles and contradiction matrix while the control group works without a formal idea generation method. TRIZ improves variety and novelty of ideas generated while decreasing the quantity of ideas produced compare to no ideation method.

Research evidence about TRIZ in idea finding may be useful but it might not be able to generalize to the pre-university students. Therefore, there is a need to investigate how TRIZ impacts pre-university students' idea finding.

Objective and Guiding Questions

This paper explores the benefits and challenges of pre-university students encounter in TRIZ program and their self-efficacy in problem solving, problem finding and idea finding after learning TRIZ. Furthermore, this paper attempts to uncover the methodologies and tools that support problem finding and idea finding. The research intended to answer the following questions:

(1) Does TRIZ program affects pre-university students' efficacy in problem solving, problem finding and idea finding skills?

(2) How TRIZ program affects pre-university students' ability in problem finding and idea finding?

(3) What is the benefits and challenges of learning TRIZ?

METHODOLOGY

Setting and Participants

A total of 28 Pre-university students in their second (n = 20) and final semester (n = 8) of study were enrolled in a TRIZ program for two days (8 hours each day) from 22nd January 2015 to 23rd January 2015.This is an embedded approach whereby students were taught the following TRIZ tools such as functional analysis, cause and effect chain analysis, trimming, 40 inventive principles and contradiction matrix.

Research Design and Data Collection Methods

The study adopted a mixed method approach, combining both quantitative and qualitative aimed at bringing to light as many aspects as possible students' perception of TRIZ program and how it impacts their problem solving, problem finding idea finding skills According to (Creswell, 2002), the combined use of quantitative and qualitative approaches provides a better understanding of research problems than either approach alone.

The quantitative study is based on one-group pre-test-post-test design. This is a preliminary study to find out students perception of their efficacy in problem solving, problem finding and idea finding skills after attending the workshop instead of the effectiveness of the program. Two interchangeable closed instruction complex problems versions A and B were created. Students were administered the pre-test just before TRIZ program. Post-test were administered at the end of the program. Fourteen students were asked to solve complex problem version A before pre-test and version B before post-test. The rest of the students attempt the complex problem in the opposite order to avoid subjects from remembering the questions and answers due to short period of time. A closed instruction is

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selected because the study test the students using their existing knowledge to find problem before generating ideas to solve them.

The students were given a 5-points Likert type questionnaire (1 = strongly agree; 2 = agree; 3 = not sure; 4 = disagree; 5 = strongly disagree), in which students express their views about problem solving, problem finding and idea finding during pre- and post- workshop. There are 2 items in the category of problem solving (I am confidence in problem solving; Problem solving skills are of vital important) and problem finding (I am never intimidated by unknown problems; I can understand problem from different direction). 1 item for the category of idea finding (I get many different ideas by thinking from different standpoints).

The qualitative study consisted of survey using open-ended questionnaire during post-test to bring some of the issues related to benefits and challenges surrounding the acquisition and application of TRIZ tools in problem finding and idea finding. The questionnaire requested the respondents to base their entries on their experiences of solving the given complex problems.

RESULTS

Students' Efficacy in Problem Solving, Problem Finding and Idea Finding

Students' efficacy in problem solving improves after TRIZ program. The mean score of students responses to the statement: 'I am confidence in problem solving' increased from 4.57 in pre-test to 4.71 in post-test and 'problem solving skills are of vital important' increased from 3.18 in pre-test to 3.93 in post-test respectively. Students' efficacy on problem finding improves after TRIZ program. The mean score of students responses to the statement: 'I am never intimidated by unknown problems' increased from 3.43 in pre-test to 4.00 in post-test and 'I can understand problem from different direction' increased from 2.79 in pre-test to 3.46 in post-test respectively. Students' efficacy on idea finding improves after TRIZ program. The mean score of students' responses to the statement: 'I get many different ideas by thinking from different standpoints' increased from 3.54 in pre-test to 4.25 in post-test. Result is summarised in Table 2.

TABLE 2 . Description of tools in TRIZ based creative problem solving module

Question	Mean	
	Pre-	Post-
1. I am confidence in problem solving	3.18	3.93
2. Problem solving skills are of vital important	4.57	4.71
3. I am never intimidated by unknown problems	2.79	3.46
4. I can understand problem from different direction	3.43	4.00
5. I get many different ideas by thinking from different standpoints	3.54	4.25

TRIZ Program and Pre-University Students' Ability in Problem Finding and Idea Finding

In an open ended survey, the students were asked about how TRIZ program affects students problem finding, ability to look at problem from different angle was mentioned the most often. Finding the root cause, breaking down the problem and identifying the parameter are the next favourite mentions as shown in Figure 3.

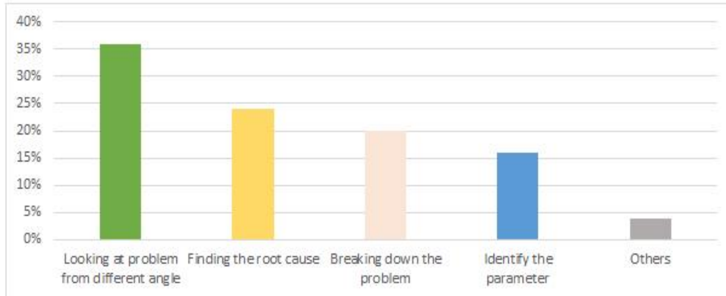

FIGURE 3 . How TRIZ program affect students' problem finding ability

As for idea finding, students' mentioned that the systematic problem solving and using system parameter and inventive principles helped them in finding new idea. Using inventive principles only, problem finding and finding the root cause are the next favourite mention. Besides that, the students have also highlighted other aspects that assists their idea finding as shown in figure 4.

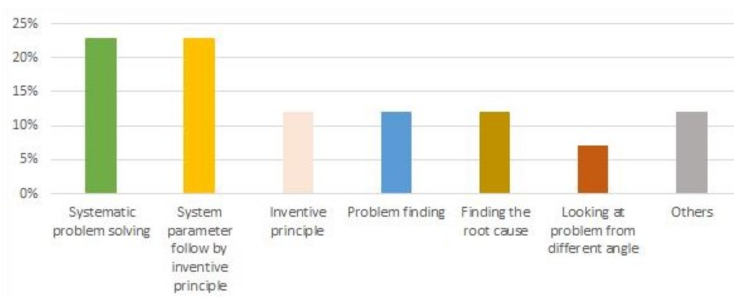

FIGURE 4 . How TRIZ program affect students' idea finding ability

Benefits and Challenges of TRIZ

Students were asked the benefits they got from attending the TRIZ program and the top four most mentioned by students are improving problem finding, improving idea finding, learning systematic way of problem solving and improving overall knowledge. The result is summarised in Figure 5.

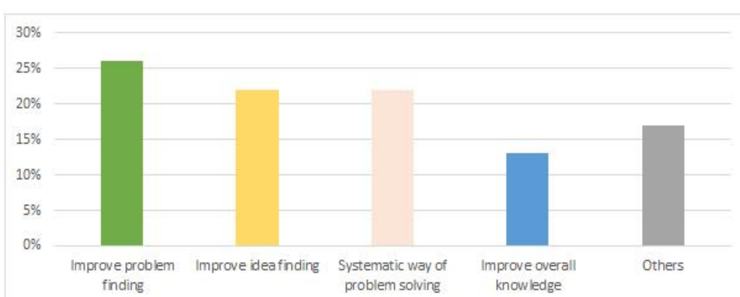

FIGURE 5 . Benefits of TRIZ program

As for the challenges of TRIZ program, students mentioned that the difficulty of finding good ideas is the most difficult challenge. Difficult to understand, insufficient time, are the next favourite mentions. There are other challenges as well mentioned by students and they are summarised in Figure 6.

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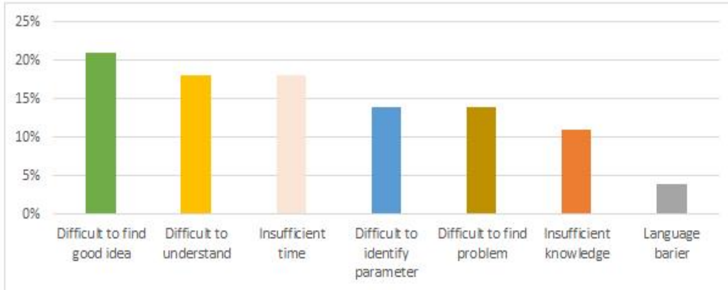

FIGURE 6 . Challenges of TRIZ program

DISCUSSION

Students' efficacy in problem solving, problem finding and idea finding increases after TRIZ program. TRIZ program can be introduced to the pre-university students using the embedded approach TRIZ program improves their problem finding because it improved their ability to see problem from different angles by breaking down the problem into component before converting the problem into a function diagram that links the various components of the system. TRIZ program taught them to find root cause of the problem also contribute to the improvement in problem finding. As for idea finding, students commented that both systematic way of problem solving and using contradiction matrix to find the inventive principles allow them to discover more ideas. Students commented that the 40 inventive principles reduced the time of finding ideas. They also mentioned that problem finding is an important step in idea finding. Once the problem is found, the idea can be generated easily. Students can be taught problem finding and idea finding through explicit instructions using TRIZ program. Similar to the finding of Chand and Mark (1993), the open ended survey showed that students have different interpretation of the same problems, so they use different strategies to find problems. In addition, students used different strategies to generate ideas. TRIZ is based on heuristic search for solution. So, students choose the best outcome in their knowledge capacity when moving through the problem space from a specific problem in search for a specific solution.

Students replied in the survey, that TRIZ program had improved their overall problem solving process. They were able to tackle the problems from different perspective. Problem can be solved in a more systematic way. Furthermore, they felt that learning TRIZ was fun. As a result, instructional module with a clear objective and appropriate reinforcement such as creating a rewarding and fun environment will foster creativity.

Students found that it was difficult to find good idea even after attending TRIZ program. Fulbright (2011) explains that students tend to generate a non-ideal "big revolutionary invention" instead of a simpler solution. Students also complained that TRIZ is difficult to understand. TRIZ is perceived to be too difficult for beginners to understand due to its technical jargon. TRIZ has been traditionally applied by TRIZ experts in the role of consultants (Bowyer, 2008). As a result, students find that TRIZ methodology is difficult to apply (Ilevbare *et al*., 2013). In addition, choosing and applying the right tools from the TRIZ toolbox to solve problems is very challenging. For example, difficulty in linking problems with the system parameter especially if the problem was unfamiliar to them, may often leads to discouragement of learning TRIZ (Rutitsky, 2010). Students complained that the program is short and the information given to them is too overwhelming. They could not absorbed too many information in such a short time. Fulbright (2011) and Ilevbare *et al*. (2013) mention that learning TRIZ required substantial investment in time and resources

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in order to understand the TRIZ concept. Student claimed that they have limited knowledge in finding the right solution. This could be due to the current TRIZ module were written for engineers which might not match students' knowledge and interests (Nakagawa, 2011). They were also limited by their own psychological inertia to find solution. Finally, some respondents found that it was hard to express their idea in English.

It is recommended that instructors come out with a new ways of teaching TRIZ to beginners such as pre-university students based on the knowledge domain that is suitable for pre-university students with lesser technical jargon. Student will be guided through each process while using TRIZ tools to solve ill-structured problem. Teaching case studies on everyday-life problems solved by previous batch of students could be used to enhance the TRIZ program. Instead of a two days program, the length of the program can be lengthened to two weeks or more to include hand on activities such as creating prototypes for problem solving so that students have time to absorb and practice.

CONCLUSION

TRIZ program improves pre-university students' efficacy in problem solving, problem finding and idea finding skills. TRIZ program provides instructions to help students find problem and find idea, however different students may have different interpretation of the same problems, so they use different strategies to find problems and ideas. TRIZ program provides students' knowledge of systematic problem solving to find problem and ideas. However, there are many challenges in learning TRIZ and the current TRIZ program is not designed for pre-universities student. As a result, it is recommended that the current TRIZ program is modified to suit the students.

LIMITATIONS AND RECOMMENDATIONS

This study is limited to pre-university problem-solvers and may not be useful and/or usable in children's or higher level students. Due to practical constraints, the number of participants in this research study is small. This is a preliminary study with the assumption that problem solving skills can be enhanced through the use of the program. The author assumes that students only use the problem finding and idea finding methods taught to them. Other variables for example, gender difference and motivation could be related to the problem solving process.

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